Fig. 1. Counter-inside display used for evaluation programme

Fig. 3. Display used in V.C.10

Fig. 2. Display used in Trident

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Report of the United Kingdom Altimeter Committee

The United Kingdom Altimeter Committee was set up by the Minister of Transport and Civil Aviation in February 1959 with the following terms of reference:-

"To investigate the design of altimeter faces and mechanisms, including the use of special visual or audible signals, and to make recommendations for the design requirements best suited to modern needs for quick and easy recognition of altitude readings."

2. The decision to form the Committee was made following two major accidents to British Public Transport aircraft that had undoubtedly been caused by misreading of the altimeter. These were the accident to the Viscount G-AORC at Prestwick on 28th April, 1958, and the accident to the Britannia G-AOVD at Hurn on 24th December, 1958. There had also been an accident to a Viscount VP-YNE owned by Central African Airways at Benina on 9th August, 1958, that was thought to have been caused by an error in altimeter reading.

3. The following organizations were represented on this Committee:-

The Air Registration Board
The British European Airways Corporation
The British Overseas Airways Corporation
The British Independent Air Transport Association
The British Air Line Pilots Association
The Guild of Air Pilots and Air Navigators
The Society of British Aerospace Companies
The Merchant Navy and Air Line Officers Association
S. Smith & Sons Ltd., (Aviation Division)
The Ministry of Aviation
The Ministry of Defence, (Navy and Air Force Departments)
The Institute of Aviation Medicine

4. A study of the more recent history of altimeter presentations showed that since 1940 there had been spasmodic attempts to consider the problem scientifically. Analyses of the types of error made in reading the conventional three-pointer altimeter that were carried out in the United States in the later 1940s made it clear that the designs of dials and the presentation of information could be improved. However, it seems that on neither side of the Atlantic was there felt to be justification to change the type of height presentation at that time in use and the main reasons appear to have been:-

(a) It was not certain that the results of experiments which were carried out in a laboratory, possibly under unrealistic conditions, would necessarily be valid in the air; and

(b) the possibility of accidents being caused by the changeover from one type of instrument to another could not be overlooked and it was felt that an improved design did not warrant such a risk.

5. During the next ten years there was little evidence to show that the decision to retain existing altimeters with unaltered presentation was an incorrect one and it is interesting to note that during this period few

complaints appear to have been made about altimeter prssentation. It must be remembered that the "three-pointer" was not entirely without merit.

6. Undoubtedly, it was the introduction into civil aviation of pressurized aircraft that normally cruised at altitudes up to 40,000 feet and in which the rate of climb and descent were high, that accentuated the problem.

7. In the course of its deliberations the Committee set up the Operational Requirements Sub-Committee, the Design Sub-Committee, the Suggestions Panel and the Trials Programme Working Party, in that order.

8. In putting its report to the Design Sub-Committee, the Operational Requirements Sub-Committee stated that any instrument or display evolved should be designed and tested on known human engineering principles and given full laboratory and in-flight evaluation under all intended lighting conditions. The Sub-Committee's report took the form of a broad technical specification of an instrument for use in high performance aircraft, with particular reference to such matters as Range, Accuracy, Readability, Scale, "Memory Jogging" Devices and Datum Indicators.

9. After a close study of the recommendations of the Operational Requirements Sub-Committee, the Design Sub-Committee expressed the view that the presentation should be on evolutionary rather than revolutionary lines and assumed that only a servo-operated instrument could provide the facilities required. It was considered that the basic information should be in digital form giving a full read-out altitude to the nearest fifty feet, and a preference was expressed for counters. It was also considered that the sensitive indication should be a pointer, revolving once every thousand feet and read against a fixed circular scale, thus giving the pilot rate information; a wide-scale display in the form of a vertical indication of thermometer type, showing the whole height in coarse form, was to be incorporated, although evaluation might show that it would not be necessary in the final version of the instrument. It was the view of this Sub-Committee that the presentation of subsidiary information, such as the command altitude and pressure setting in inches or millibars, should be of the digital counter type and sited outside the main display.

10. All bodies represented on the Sub-Committee contributed to the exhaustive discussions in detail and it can be said that in their opinion the recommendations summarized the technical, aero-medical and potential users' considered views.

11. The Suggestions Panel examined some 200 suggestions, from members of the public, professional sources and instrument manufacturers. Many were variations of the three-pointer instrument and all were inferior to, or offered no advantage over, similar instruments already available. The method adopted was to examine each proposal individually. First it was considered as a possible altimeter without regard to conventional instruments. It was then reviewed in the light of authoritative research such as the IAM Paper entitled "A Comparison of Fourteen Altimeters", March, 1959, supported by technical and flying experience. Finally the suggestion was measured against the recommendations of the Operational Requirements and the Design Sub-Committees.

12. The Trials Programme Working Party was set up with the following Terms of Reference:-

(i) To draw up a programme to be followed in testing and evaluating the recommendations of the Design Sub-Committee;

(ii) to consider and report on the number and design of models neoessary for the programme;

(iii) to investigate and report on the facilitiee available for the conduct of the neoesary trials.

From an examination of the work of the Design Sub-Committee the Working Party oonoluded that the following were the principal points first requiring evaluation:-

(a) The rate of ohangeover of basio indication;

(b) the number of digits on the basio indioation;

(c) the value of and possible need for a widescale display;

(d) oomparieon of the oommand altitude and basio altitude indicators with a view to establishing whether there was a need for a speoifio indioation of attainment of oommand altitude.

13. It was oneidered essential that those charged with ths oonduct of the Triale Programme ehould bear in mind that the aim was to produce an altimeter which wae clear and explicit under all operating oonditions. It wae pointed out that eubsidiary teste, euch ae the efficiency of the oommand altitude indioator, must not divert attention from this prime purpoee.

14. Following the Report of the Altimeter Committee, a Control Group, oomprising several members of the Main Committee, was eet up to progress the oonduot of the trials and to reoeive and discuss the reporte of the Royal Air Foroe Institute of Aviation Medicine, whioh was responsible for the evaluation.

15. As a reeult of this work, four displaye were passed to the I.A.M. for evaluation; I.A.M. had iteelf studied the epeoifioation and produced three further dieplaye for inolusion in the programme. The reaeon for this etep was that all four of the original dieplaye had the digital oounter mounted inside the oirculer ecale (counter inside display) where it could be obeoured by the revolving pointer. I.A.M. suggested an alternative form of the display where the digital counter was mounted outeide and above the oirculer ecale (counter outeide display).

16. The Institute of Aviation Medicine considered that the only satiefactory evaluation would be one whioh employed a range of teohniquee, each deeigned to study particular aspeots of the dieplay. There should be a general evaluation by reference to non-experimental data and to the subjective opinions of expert usere. Next, experiments using statio prseentation to etudy readability followed by ths use of dynamio models in a simple task syetem, the programme being completed by a study of the dieplay as part of the panel in a eimulator and then to go on to the same form of evaluation in ths air.

17. A literature eearoh resultsd in ths oompilation of a bibliography and oheok list of human engineering data on altimeter display against which all displaye were assessed to ensure that no major deeign errors were present. Booklets oontaining pictures of the seven expsrimental displays and two existing altimetere were prepared and administered to a representative sampls of 230 civil and military pilots. Subjsots were asked to ohooee the two

best and two worst displays and to comment on the merits and faults of each display. In addition some 16 human engineers also acted as subjecte.

18. This first stage resulted in the demonstration of the wide agreement that exieted between pilote, both civil and military, as to what they considered were the features of a good display and also general disapproval of multi-pointer instrumente. From the reeulte of the eurvey and the check list assessments it wae decided to reduce the number of displays to two. Eaoh of these had a pointer and a five digital indioation, with the digits moving downwards as height inoreaeed; in one display the digits were situated in-eide the oirculer soale, ae preferred at that stage by many of the pilots queetioned, while in the other the digite were mounted outside, and above the oirculer scale, an arrangement that was ooneidered more acceptable from the human engineering point of view, ae well as having some support from pilots. It wae decided that a command height indioation should be provided as a separate dieplay if required, and that for civil operation a wide scale dis-play was unnecessary. A multi-pointer display was ohosen ae the control for the static experiments.

19. The second stage investigated the value of the dieplay from one aspeot of its operational use, ite ability to be read aoourately and quickly. The usual way of assessing this in the laboratory is to present the dieplay, or photographs of the display, in a variety of readings to the subjeots and to measure their reading aocuracy under highly controlled brief time exposures ueing a taohistoscope.

20. The I.A.M. considered the "experimenter determined" exposure time would be unrealistio and oonsequently the teohnique employed was the "eubjeot determined" expoeure time. In other words the only oommand in the task was to ask the subjeot for a reading of his experimental display; he began the exposure when he himself wae ready and he ended the exposure when he was satisfied that he had read the display. Any mistake made in this situation oould then clearly be aesigned ae an error in interpretation of the display. The I.A.M. suggest that this teohnique of the "subjeot determined" exposure is closer to the real life situation, when attention is divided between a number of information sourcee each requiring scrutiny; the operator does not give each display a predetermined glance and hazard a reading, but dwells on each display just as long as it is necessary to obtain a reading, while all the time keeping in mind that other displays demand attention.

21. To aohieve this situation in the laboratory experiment the further task introduoed wae a continuous tracking display requiring oonstant attention, but making it impossible to assimilate information from both displays at once by using a mirror tachistoscope. Normally the subjeot saw the tracking dis-play, but when asked for an altimeter reading he pressed a button whioh brought up the altimeter display and at the same time removed the tracking display. Consequently the subjeot knew that although he could choose his own reading time, his performance on the second task would be greatly affeoted by prolonged reading of the altimeter. This method of statio evaluation not only has the advantage of being a more realistio experimental situation, but it also providee more expsrimental data. The fixed exposure telle only what errors were made by subjeots who had no choice of time for their reading. The "subjeot determined" exposure provides a measurs of the subjeot's reading time, the number of errore that ooourred in reading the display, and the "srror score" on the tracking task.

22. The results of this etatio trial showed no signifioant difference between the two oounter/pointer displays. Reading time on both was oonsistently one

third of thet of the multi-pointer dieplay; tracking errors wers less when reeding the counter/pointer displays than when reading the multi-pointer display. No errors were made on either of the counter/pointsr displays, while one quarter of the readings of the multi-pointer display were in error by one hundred feet or more. The majority of the pilot subjects stated a prsference for the counter outside display because of its freedom from pointer obscuration.

23. For the final dynamic stage in the laboratory evaluation mechanical modele were incorporeted in a simple control system demanding responses similar to those encountered when height changing end height maintaining in an aircraft. The subjects were pilots, one hundred in all, drawn from both military and oivil flying.

24. For the height chenging phase a programme was devised that allowed observation of subject performance on the displays whsn increasing and decreasing height. With rsgard to the rate of chengeover of basio indication referred to at (a) of para. 12, an existing mechanism was used for this part of the evaluetion and it was concluded that the chengeover should be a continuous movement taking place between 950 and 1,000 feet. Measuree wers made of the time taken to complete the required change and the pattern of control movemente made during the change. In the experiments on height keeping, subjecte attempted to keep the display readings within prescribed limits, while an srror systsm was at work tending to make the setting wander above and below the required height.

25. The results of this phase indioated that while there wes no marked difference in the subject's performance on the two displays when changing height, in the height keeping phase the counter inside display by virtue of ite larger sweep ecale allowed significently more acourate tracking than the counter outside display. Overall subject assessment during the dynamic trials changed from favouring ths counter outeide display to favouring the counter inside display. This change of opinion is attributed, in addition to easier height keeping, to the tendency of the counter outeide display to appear as two independent displays demanding an alternation of attention. The obscuration of the digital counters by the pointer on the counter insids display was no longer considered important, beoause in the dynamic situation the drums were never obscured for long enough to make readings difficult, as in the static situation when photographe were used.

26. At the cloee of this stage the researoh passed from the laboratory to the flight eimulator. The Simulator Trials showed the same general pattern as the dynamio laboratory experiments with the counter insids display bsing preferred to the counter outside. It was also shown that the possibility of the counter outeide display being mistaken for two separate instruments was accentuated when the display was mounted in a panel with other instruments. In particular, if the display was mounted above the vertical speed indicator, the circular scale of the altimeter was often mistaken for the V.S.I. and on this assumption unneoessary and incorreot responses were made.

27. In the Flight Trials, which were the final stage of the evaluation, the displaye were part of the actual flying complex. The data from a total of 96 reports from B.E.A. and B.O.A.C. showed that there was a marginal preference for the counter outside display. On both displays, because of the use of a digital height display, there is a tendenoy when descsnding to level off early above the required altitude. The largeet possible error is 950 fest and is always a "safe" error in so far as terrain olearance is oonoerned

becauee the error is above and not below the required altitude. Both the dynamic and flight trials showed that thie error could occur, but indicated that it took place only during familiarization with the display and disappeared with preotice. It ie therefore recommended that when displaye of thie type are introduced into service, orews should be required to familiarize themeelvee with the displays on the ground, using a flight eimulator or eome form of training device.

28. Suoh a study as thie has naturally resulted in speculation ae to the linee along which future reeearoh might be directed. It is thought that consideration ehould first be given to the poeeibilities of oombining altitude and vertical epeed information, and secondly, to the uee of all digital indication (e.g. countere). It is also thought that it is important to eneure that any evaluation programme ehould possess both operational and methodological validity, i.e. the right questions ehould be asked and the relevant methods ueed to obtain answere.

29. Full details of the reeearoh work on which this Report ie baeed appear in I.A.M. Report No. 253 prepared by J. M. Rolfe. Copiee may be borrowed from the Central Library, Minietry of Aviation.

CONCLUSIONS

30. The evaluation programme as a whole has ehown that the counter/pointer display is markedly euperior to the three-pointer type of display. Of the two displays teeted, neither had a significant advantage over the other, but the United Kingdom Altimeter Committee expresses a preference for the counter inside presentation, whioh is already in fairly wide uee in military and oivil airoraft both in this country and abroad.

31. The United Kingdom Altimeter Committee therefore recommends a counter/pointer dieplay with the counter situated ineide the dial. The counter inside display that was used for the evaluation programme is shown in Fig. 1. The displaye at preeent in use in the Trident and V.C.10, both of whioh are based on recommendations made by the Committee, are shown in Figs. 2 and 3.

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MINISTRY OF AVIATION

REPORT OF THE UNITED KINGDOM ALTIMETER COMMITTEE

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January, 1965.

The Minister of Aviation

Sir,

I have the honour to submit the Report of the United Kingdom Altimeter Committee.

I have the honour to be,

Sir,

Your obedient Servant,

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